TECHNICAL INFORMATION ON BUILDING MATERIALS

FOR USE IN THE DESIGN OF LOW-COST HOUSING

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THE NATIONAL BUREAU OF STANDARDS
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STUDY OF UNDERGROUND CORROSION OF NONBITUMINOUS METAL COATINGS

This paper gives the results of findings on a series of tests begun by the Bureau in 1922 on nonbituminous coatings of metals for underground use. A more detailed account of these findings is reported in Research Paper RP982, "Soil Corrosion Studies",[1] from which the material in this paper has been taken.

The specimens used in the tests were iron and steel pipe and sheet, coated with three metallic, and ten nonmetallic coatings. The specimens were buried in different soils throughout the country, the more frequently used types of soils being described briefly as follows:

(13) Hanford very fine sandy loam - fair drainage - alkaline - 21.7% moisture equivalent.[2]
(24) Merrimac gravelly - sandy loam - good drainage - acid - 13% moisture equivalent.
(28) Montezuma clay adobe - poor drainage - 24.6% moisture equivalent.
(58) Muck - very poor drainage - very acid - 57.8% moisture equivalent.
(42) Susquehanna clay - poor drainage - very acid - 34.8% moisture equivalent.
(43) Tidal marsh - very poor drainage - very acid - 55.4% moisture equivalent.
(45) Unidentified alkali (Casper, Wyo.) poor drainage - alkali - 14.8% moisture equivalent.

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[1] May be obtained from the Superintendent of Documents, Washington, D. C. (Price 10 cents).

[2] The moisture equivalent is the percentage of moisture the soil will retain against a centrifugal force of 1,000 gravity.

Lead-Coated Pipe

Three separate tests were made with lead-coated pipe: one for ten years; one for eight years; and the third for two years. The coatings for all three tests had an average thickness of from one, to one and one-half thousandths of an inch. Together with the coated specimens, uncoated pipes were included as a matter of comparison. In several of these comparisons the rates of maximum penetration were greater for the coated specimens. This can be explained by the fact that when the iron or steel beneath the coating has been exposed, galvanic action between the two metals frequently accelerates the corrosion of the ferrous metal, and the lead-coated pipe may be punctured before an uncoated one of the same pipe-wall thickness.

The following tables give comparative results obtained from these tests in the seven different soils described above.

RATES OF LOSS
($Oz/ft^2/yr$)

Soil	Lead-Coated Steel			Bare Steel		
	10 yrs	8 yrs	2 yrs	10 yrs	8 yrs	2 yrs
13	.064	.18	–	–	1.70	–
24	.033	.08	–	.12	.21	–
28	.314	1.09	–	1.75	–	–
58	–	–	.87	–	–	1.85
42	.092	.44	–	.95	.89	–
43	.726	.77	–	1.47	.86	–
45	.198	1.27	–	.79	2.64	–

RATES OF MAXIMUM PENETRATION
(Thousandths of an inch per year)

Soil	Lead-Coated Steel			Bare Steel		
	10 yrs	8 yrs	2 yrs	10 yrs	8 yrs	2 yrs
13	5.4	6.5	–	–	19.3	–
24	2.2	3.3	–	2.1	3.7	–
28	7.8	9.1	–	15.1	–	–
58	–	–	14.8	–	–	9.0
42	4.6	7.4	–	7.1	8.8	–
43	18.8	18.0	–	8.7	10.8	–
45	9.2	10.1	–	6.9	16.6	–

It is believed that these data justify the conclusion that thin lead coatings in general are not suitable for protecting steel pipe against soil corrosion.

Calorized Pipe

Calorizing is the commercial name for the cementation of a metal surface by means of aluminum. The coating is an alloy of aluminum with the base metal. There are two processes of calorizing, one known as the powder or dry process, and the other as the dip or wet process. Specimens of pipe calorized by each process were placed in seven soils in 1924. The rates of corrosion of the calorized specimens, together with the corresponding data for unprotected steel are given in the following table:

Soil	RATES OF LOSS OF WEIGHT ($Oz/ft^2/yr$)			RATES OF MAXIMUM PENETRATION (Thousandths of an inch per year)		
	Dry Calorized	Wet Calorized	Bare Steel	Dry Calorized	Wet Calorized	Bare Steel
13	0.137	0.087	1.24	3.4	4.4	13.0
24	.019	.013	0.12	2.4	3.2	2.1
28	.437	-	1.75	5.5	-	15.1
42	.452	.088	1.25	7.0	4.2	9.2
43	.861	.434	1.72	3.1	3.4	7.4
45	.712	.184	1.23	3.4	4.4	11.9

An examination of this table shows that specimens calorized by the dry or powder process showed somewhat higher rates of loss of weight and somewhat smaller rates of maximum penetration than those calorized by the dip process.

Galvanized Pipe and Sheet

Galvanized iron prepared by the hot-dip process includes an outer layer of nearly pure zinc; a middle zone of one or more alloys of zinc and iron; and finally, the metal to which the zinc was applied. The thickness of the alloy layer depends upon the methods used in galvanizing, and to some extent on the character of the base metal. It is not practicable to apply an exact amount of zinc or to apply the zinc as a perfectly uniform coating by hot-dip process as used commercially. For these reasons, and because of nonuniform soil conditions, the determination of the effect of each factor in the corrosion of galvanized specimens under field conditions would be very difficult, if not impossible, even with a very large number of specimens. From the available data, it is possible to draw general conclusions only. A summary of data on specimens with nominal two-ounce coatings is given in the following table:

AVERAGE RATE OF LOSS OF WEIGHT
($Oz/ft^2/yr$)

Material	Weight of coating	6 years exposure in 38 soils	8 years exposure in 19 soils	10 years exposure in 39 soils
Bessemer steel sheet	0.81	0.091	0.145	0.169
Open-hearth iron sheet	.99	.081	.128	.147
Copper-bearing steel sheet	1.07	.095	.133	.132
Open-hearth iron pipe	2.82	.091	.185	.133

A principle applicable to protective coatings, in general, is that if the life of unprotected material is short either because of the thinness of the material or the corrosiveness of the soil, a protective coating will probably increase the life of the structure sufficiently to justify its use. If, however, the life of the structure is long, the desirability of a coating is more questionable. Thus, the use of galvanized rather than black corrugated iron culverts might be economical, although the use of large-diameter galvanized water pipes might not be advisable. Galvanized coatings for underground use should have a weight of at least two ounces of zinc per square foot of pipe surface.

In the following table comparative figures are given for the pit depths in different metals exposed over a period of 10 years. The galvanized pipe had a coating of 2.82 oz. per sq. ft. while the copper-bearing steel had a coating of 1.08 oz. per sq. ft.

CONDITION OR RATES OF MAXIMUM PENETRATION
(Mils per yr)

Soil	Bessemer steel No coating	Galv. iron pipe $2.82\ oz/ft^2$	Copper – bearing steel sheet $1.08\ oz/ft^2$
13	–	R	0.8
24	2.1	Z	Z
28	15.1	R	2.3
42	7.1	R	1.2
43	8.7	A	R
45	6.9	R	1.5

Z = Zinc still visible over entire surface of a specimen.
A = Alloy later exposed over at least a part of specimen but no rust.
R = Specimen rusty over at least a part of surface.

A further test to determine the relative rates of corrosion of zinc, steel, and galvanized steel, exposed to five soils for approximately ten years indicates for the period of exposure involved, and for the soils from which comparison can be made, that zinc corroded less rapidly than steel and that galvanized steel corroded least of all.

MISCELLANEOUS NONMETALLIC COATINGS

The following nonmetallic coatings were exposed for approximately two years to fourteen soils: synthetic rubber, vitreous enamel, rubber paint, unidentified paint, cashew-nut oil-asbestos-fiber paint, hard rubber, loaded hard rubber, synthetic resin varnish, chlorinated rubber paint, china wood oil-mica plastic. The thin coatings employing a volatile solvent were not as satisfactory as the thicker coatings. The types of failures differed for different coatings and for different soils. Several of the coatings were experimental in nature and the data are insufficient to indicate whether or not they would be practicable.

Summary

The following are some of the more important conclusions based on the data presented:

With the exception of the lead-coated specimens, all of the coatings treated in this report appear to have reduced the rate of corrosion of steel during the period of the test.

None of the coatings have a perfect record for all specimens removed, although in some cases of short-time exposures the rusting of the protected pipe was probably caused by moisture entering through the ends of the specimens and not through the coating.

Lead is sufficiently corrodible in most soils to result in the perforation of lead coatings of the thickness used in these tests within 10 years. After the lead has been punctured, accelerated corrosion may occur because of differences of potential between lead and steel.

Over a 10-year period, the rates of loss of weight of galvanized steel were from one-half to one-fifth the rates for bare steel.

Galvanized steel corrodes most rapidly in poorly drained acid soils and in those high in salts.

For long periods of exposure, thick zinc coatings are superior to thin ones. A coating of 2.8 ounces per square foot of exposed surface prevented the formation of measurable pits in all but one soil for a period of 10 years.

The type of ferrous material to which the zinc is applied does not have an appreciable effect on the rate of corrosion of galvanized materials during the first 10 years of exposure.

Of a group of nonmetallic and nonbituminous coatings, vitreous-enamel and hard-rubber coatings afforded the best protection over a two-year period of exposure.